SAND2016-4558C

UPDATE
High Performance Computing Power Application Programming Interface (API) Specification

H. Laros III
ia National Laboratories
http://powerapi.sandia.gov

Sandia National Laboratories

- Version 1.2 Released February 2016
  - Changes were predominately a result of our collaboration with Cray on the Trinity Power APM NRE
- Version 1.3 *to-be-released* May 2016
  - Statistics interface
  - New Object (HT)
  - New Attribute (GOV)
- Version 2.0 *release-TBD* 2016 Python bindings
- Trinity APM NRE
  - Cray and Adaptive collaborations
- Discussions with Geo
- Discussions with RedFish

Trinity APM NRE

Sandia National Laboratories

- APM – Advanced Power Management
- NRE – Non-recurring Engineering
  - Investment part of the NNSA Advanced Technology System platform acquisition strategy
- 3 General Areas:
- Cray: Power Management Database (PMDB) interface
  - Provide access to Cray's PMDB
  - Core and selected higher-level interfaces
  - Implemented in Python – to-be released in Version 2.0 of specification
- Cray: Compute node interface
  - Node level C implementation
  - Core and selected higher-level interfaces
- Adaptive Computing: Power Aware Scheduling
  - Exercise certain aspects of Cray's implementation
  - Use case driven - scheduling within power constraints

- ***All capabilities will be implemented on the production Trinity Platform***

Power API and Geo Alignment

Sandia National Laboratories

- Power API Today:
  - Application “Hints” Interface
    - Recognize or hint about application regions
      - E.g. compute, IO, parallel, serial
- Geo Today:
  - Labeling regions which allows
    - I’m repeating a previous region
    - Time a region
    - Evolving or “learning” about regions
- Power API Tomorrow:
  - Evolve the Hints interface (or create new interfaces) to align with and expose Geo capabilities
- Good example of portability across runtime layers
  - Geo as the underlying runtime
  - Portable to “other” runtimes with similar capabilities

Power API and Redfish Alignment

Sandia National Laboratories

- Power API Today: core interfaces
  - “Common” set of interfaces for power measurement and control
- Redfish Today:
  - Provides out-of-band abstracted interface to the underlying implementation
    - Replaces IPMI-over-LAN
  - Inband later? (see Redfish talk)
- Power API Tomorrow:
  - Tools built using Power API interfaces could be portably used on systems that implement Redfish
  - Tools remain portable to other systems
  - Also to other Role->System pairs that are not applicable to Redfish
- Another example of enabling portability
  - This time using an emerging DMTF standard underneath

Going Forward

Sandia National Laboratories

- How do we move forward?
- What “standards” model to apply?
- Regular calls?
  - Frequency?
- Face to Face meetings
  - Frequency?
- Important to have broad community participation which includes vendor representatives

Thank you – Questions?

Sandia National Laboratories

http://powerapi.sandia.gov/

Acknowledgments:

This work was funded through the Computational Systems and Software Environment sub-program of the Advanced Simulation and Computing Program funded by the National Nuclear Security Administration

Backup Slides

Sandia National Laboratories

Overview

Sandia National Laboratories

- This will be a 10,000 foot view
  - The specification is necessarily broad in scope
  - Covering the specification in detail takes many hours
- A bit of history
- Collaboration from the start
- Important core principles
- Some higher level concepts
- Moving forward

Who is Behind PowerAPI?

Sandia National Laboratories

James H. Laros III, David DeBonis, Ryan Grant, Suzanne M. Kelly, Michael Levenhagen, Stephen Olivier, Kevin Pedretti

IBM

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Los Alamos
NATIONAL LABORATORY
EST. 1943

intel

Lawrence Livermore National Laboratory

NERSC

Adaptive
COMPUTING

PENGUIN COMPUTING
EXPERTS IN HIGH PERFORMANCE COMPUTING SOLUTIONS

Sandia National Laboratories

AMD

UNM

Hewlett Packard Enterprise

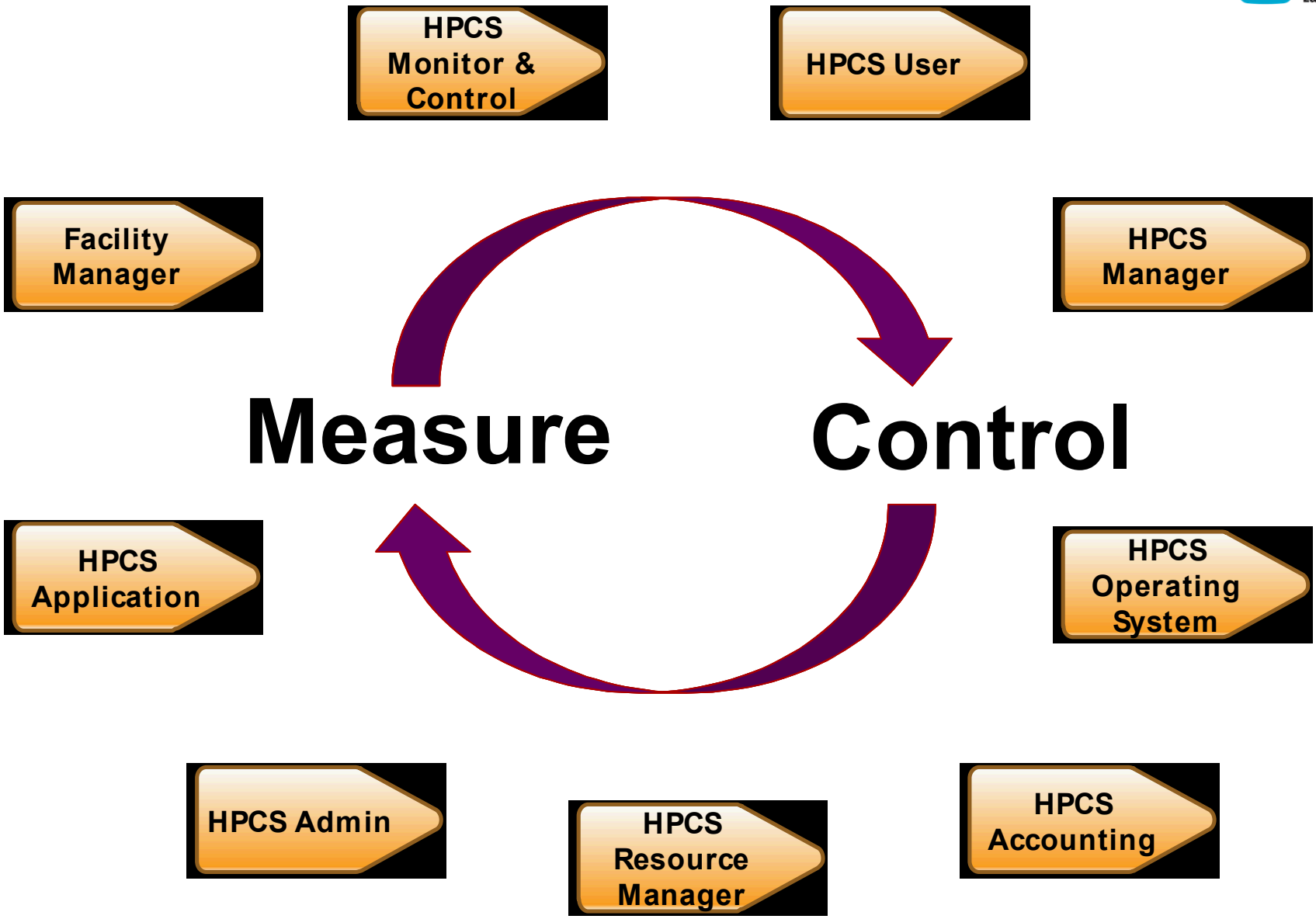
CRAY
THE SUPERCOMPUTER COMPANY

RNET
Technologies, Inc.

<Your logo here!>

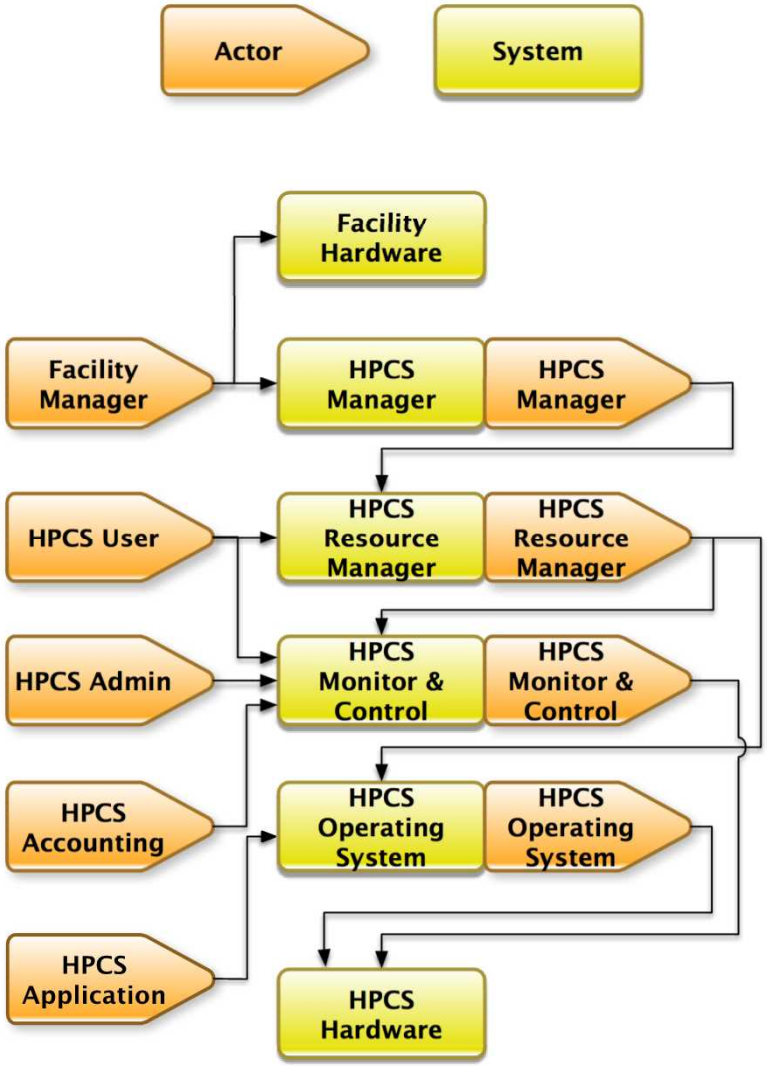
OAK RIDGE National Laboratory

EEHPC
ENERGY EFFICIENT HIGH PERFORMANCE COMPUTING


HPCS Monitor & Control
HPCS User
Facility Manager
HPCS Manager
Measure
Control
HPCS Application
HPCS Operating System
HPCS Admin
HPCS Resource Manager
HPCS Accounting

A UML-ish Approach

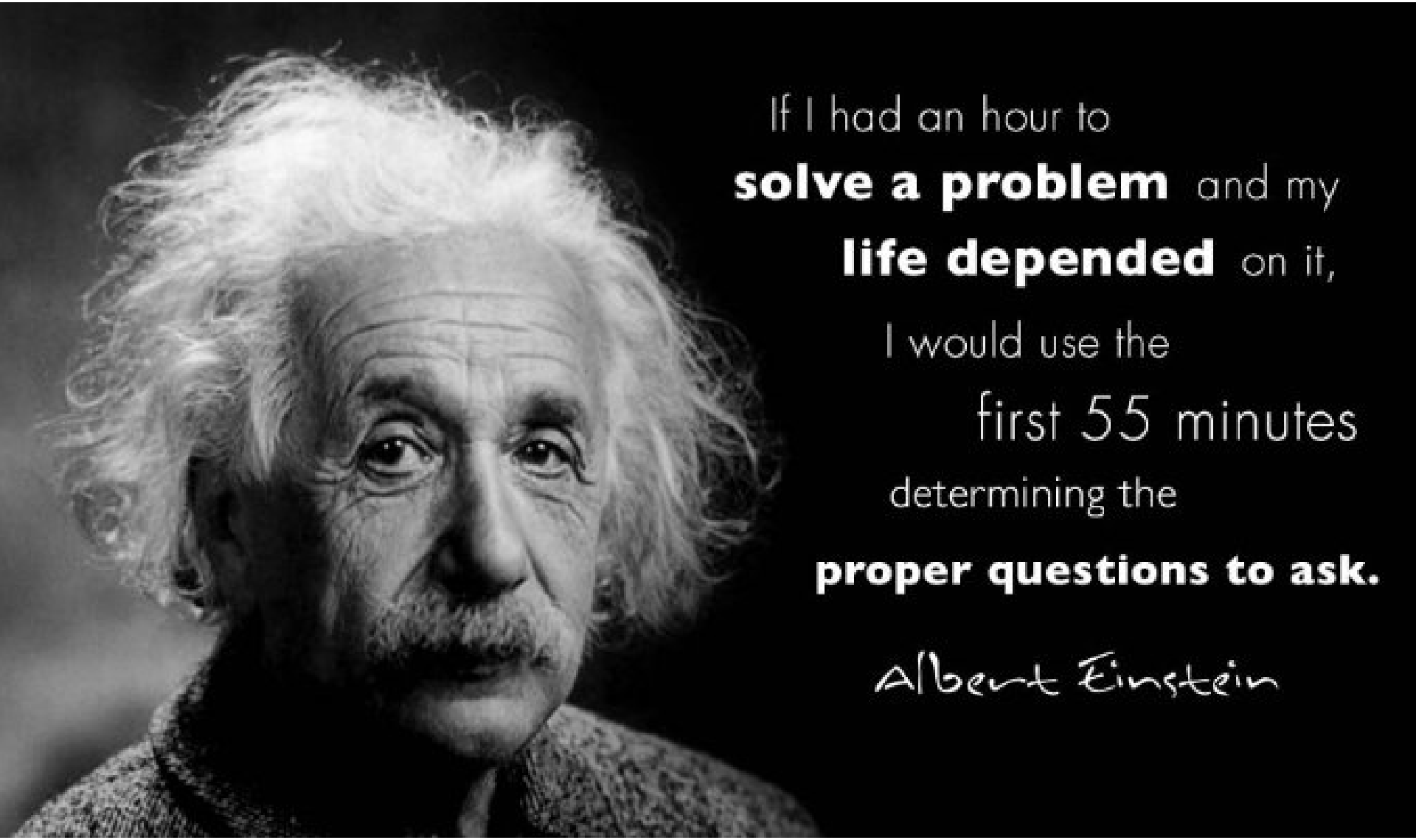
- Diagram is the result of a UML study of the target space
  - Goal: Define Scope, Roles and Interfaces
- Arrows indicate interfaces or interaction between an Actor (Role) and System
  - Each interaction represents an interface that is defined in the specification
  - Specification is structured from the user or Role perspective
- Notice that an Actor (Role) can also be a System
- Cite use case document



Goals

Sandia National Laboratories

- Portability for the HPC community
  - Wouldn't it be nice to develop tools that worked on all your machines with little to no modification?
  - Same desire exists no matter what Role you play
    - More about Roles later
- Forecast emerging needs of HPC community
  - As a group, inform the vendors of how we want to use systems now and in the future
  - Specification acts as a basis of collaboration
- Expose new capabilities developed by vendors and community
  - Leverage vendor and community innovations in this and related spaces
  - E.g. Geo and Redfish
- Most important, want something out there to throw stones at
  - Need a starting point!


If I had an hour to
solve a problem and my
life depended on it,
I would use the
first 55 minutes
determining the
proper questions to ask.
Albert Einstein

What is the Power API?

Sandia National Laboratories

A comprehensive API for power **MEASUREMENT** and **CONTROL** of HPC platforms

- *Comprehensive = Facility to Component*
- *API = Define the inter**FACE** not the mechanism*
- *HPC platforms = Facility (or datacenter) and all the platforms within*

Considers all users of HPC platform - people and programs

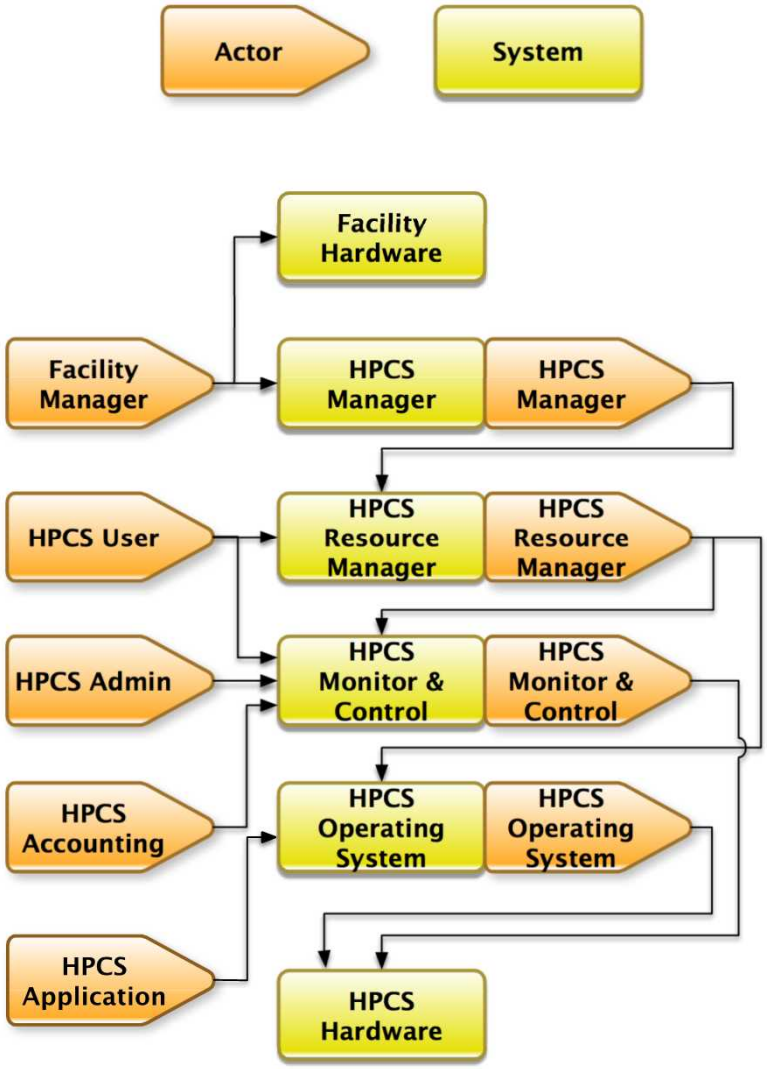
- *Core (Common)*
  - *Common among all "users"*
    - *Includes: Roles, Initialization, Navigation, Objects and Groups, Attributes (Get/Set), Metadata and Statistics*
- *High-Level Common*
  - *Higher level of abstraction but still potentially common among multiple Roles*
- *Role/System Specific*
  - *Higher level abstraction specific to how Role interfaces with system*

Roles

Sandia National Laboratories

PWR_Role

```
typedef enum {
            PWR_ROLE_APP, /* Application */
            PWR_ROLE_MC, /* Monitor and Control */
            PWR_ROLE_OS, /* Operating System */
            PWR_ROLE_USER, /* User */
            PWR_ROLE_RM, /* Resource Manager */
            PWR_ROLE_ADMIN, /* Administrator */
            PWR_ROLE_MGR, /* HPCS Manager */
            PWR_ROLE_ACC /* Accounting */
} PWR_Role;
```



Roles

Sandia National Laboratories

- Application – Application or application library executing on the compute resource; May include run-time components running in user space
- Monitor and Control -- Cluster management or Reliability Availability and Serviceability (RAS) systems, for example.
- Operating System -- Linux or specialized lightweight kernels and privileged portions of run-time systems. Privilege escalation layer.
- User -- The end user of the HPC platform.
- Resource Manager – Can include work load managers, schedulers, allocators and even portions of run-time systems that manage resources.
- Administrator – System administrator or day-to-day platform manager.
- HPCS Manager -- Individual(s) responsible for managing policy for the HPC platform, often through scheduling policy. Implements facility parameters.
- Accounting -- Individual or software that produces reports of metrics for the HPC platform.

System Description

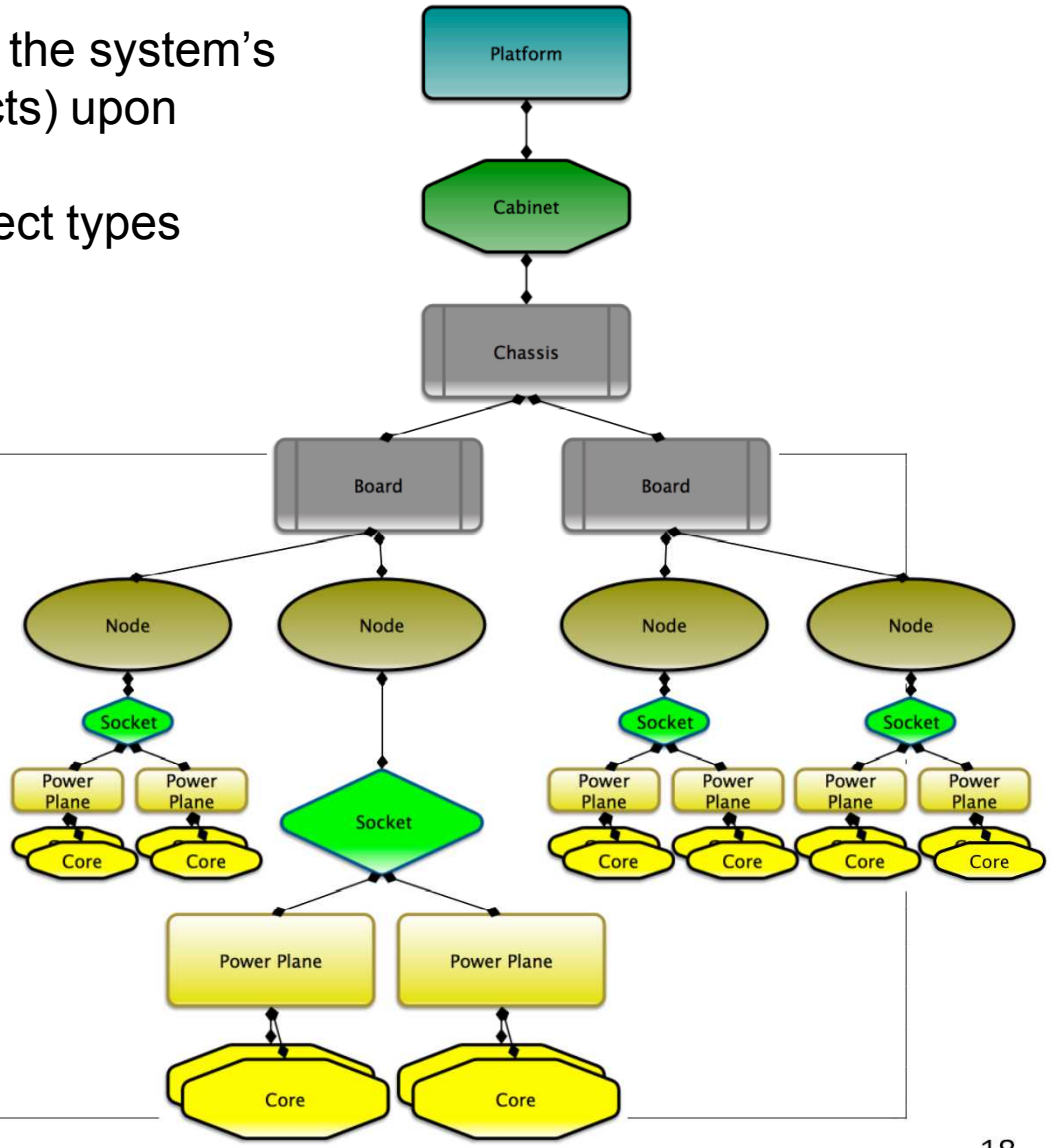
Sandia National Laboratories

Presents a navigable view of the system's hardware components (objects) upon initialization

- Can extend to custom object types
- Can be heterogeneous

PWR_ObjType

```
typedef enum {
        PWR_OBJ_PLATFORM = 0,
        PWR_OBJ_CABINET,
        PWR_OBJ_CHASSIS,
        PWR_OBJ_BOARD,
        PWR_OBJ_NODE,
        PWR_OBJ_SOCKET,
        PWR_OBJ_CORE,
        PWR_OBJ_POWER_PLANE,
        PWR_OBJ_MEM,
        PWR_OBJ_NIC,
        PWR_NUM_OBJ_TYPES,
        /* */
        PWR_OBJ_INVALID = -1,
        PWR_OBJ_NOT_SPECIFIED = -2
} PWR_ObjType;
```



Objects

Sandia National Laboratories

- Objects and Groups
  - Objects represent components of a system
    - Lots of flexibility in what a component is
  - System Description is the organization of these objects to represent the system
  - Representation may be dependent on Role (and other considerations)
  - Attributes (later) are associated with objects
  - Groups can be implementation (predefined) or user defined (long or short lived)
- Navigate the system description provided upon Initialization
  - Entry point may depend on Role
    - Node entry point for Application
    - Platform entry point for Administrator
  - Navigate up (parent object), down (child objects)
  - Navigation can also be thought of as Discovery

Attribute Interface

Sandia National Laboratories

```
typedef enum {
        PWR_ATTR_PSTATE = 0, /* uint64_t */
        PWR_ATTR_CSTATE, /* uint64_t */
        PWR_ATTR_CSTATE_LIMIT, /* uint64_t */
        PWR_ATTR_SSTATE, /* uint64_t */
        PWR_ATTR_CURRENT, /* double, amps */
        PWR_ATTR_VOLTAGE, /* double, volts */
        PWR_ATTR_POWER, /* double, watts */
        PWR_ATTR_POWER_LIMIT_MIN, /* double, watts */
        PWR_ATTR_POWER_LIMIT_MAX, /* double, watts */
        PWR_ATTR_FREQ, /* double, Hz */
        PWR_ATTR_FREQ_LIMIT_MIN, /* double, Hz */
        PWR_ATTR_FREQ_LIMIT_MAX, /* double, Hz */
        PWR_ATTR_ENERGY, /* double, joules */
        PWR_ATTR_TEMP, /* double, degrees Celsius */
        PWR_ATTR_OS_ID, /* uint64_t */
        PWR_ATTR_THROTTLED_TIME, /* uint64_t */
        PWR_ATTR_THROTTLED_COUNT, /* uint64_t */
        PWR_NUM_ATTR_NAMES,
        /* */
        PWR_ATTR_INVALID = -1,
        PWR_ATTR_NOT_SPECIFIED = -2
} PWR_AttrName;
```

Attribute Interface

Sandia National Laboratories

MEASURE

```
int PWR_ObjAttrGetValue( PWR_Obj object,
                         PWR_AttrName attr,
                         void* buf,
                         PWR_Time* ts);
```

CONTROL

```
int PWR_ObjAttrSetValue( PWR_Obj object,
                         PWR_AttrName attr,
                         void* buf );
```

Symmetric calls available for operating on groups of objects

Attributes: Common Functionality

Sandia National Laboratories

- Attributes (measure and control) of objects and groups of objects
  - Access dependent on Role and other implementation specific considerations
- Get and Set operations enable basic measurement and control for the exposed object attributes (and groups of objects)
- Attributes can represent generic measurement and control features
  - Power, Voltage, Current, Frequency
- Architecture specific features are permissible at the lowest levels
  - Pstate, Cstate may not be meaningful for all architectures
- An attribute, like power, can represent an instrumentation point or a summation of underlying instrumentation points
  - Power attribute of a CPU object
  - Power attribute of a Node object

Metadata Interface

Sandia National Laboratories

```
typedef enum {
        PWR_MD_NUM = 0, /* uint64_t */
        PWR_MD_MIN, /* either uint64_t or double, depending on attribute type */
        PWR_MD_MAX, /* either uint64_t or double, depending on attribute type */
        PWR_MD_PRECISION, /* uint64_t */
        PWR_MD_ACCURACY, /* double */
        PWR_MD_UPDATE_RATE, /* double */
        PWR_MD_SAMPLE_RATE, /* double */
        PWR_MD_TIME_WINDOW, /* PWR_Time */
        PWR_MD_TS_LATENCY, /* PWR_Time */
        PWR_MD_TS_ACCURACY, /* PWR_Time */
        PWR_MD_MAX_LEN, /* uint64_t, max strlen of any returned metadata string. */
        PWR_MD_NAME_LEN, /* uint64_t, max strlen of PWR_MD_NAME */
        PWR_MD_NAME, /* char *, C-style NULL-terminated ASCII string */
        PWR_MD_DESC_LEN, /* uint64_t, max strlen of PWR_MD_DESC */
        PWR_MD_DESC, /* char *, C-style NULL-terminated ASCII string */
        PWR_MD_VALUE_LEN, /* uint64_t, max strlen returned by PWR_MetaValueAtIndex */
        PWR_MD_VENDOR_INFO_LEN, /* uint64_t, max strlen of PWR_MD_VENDOR_INFO */
        PWR_MD_VENDOR_INFO, /* char *, C-style NULL-terminated ASCII string */
        PWR_MD_MEASURE_METHOD, /* uint64_t, 0/1 depending on real/model mesurement */
        PWR_NUM_META_NAMES,
        /* */
        PWR_MD_INVALID = -1,
        PWR_MD_NOT_SPECIFIED = -2
} PWR_MetaName;
```

Metadata: Common Functionality

Sandia National Laboratories

- Metadata interface provides information about quality, frequency, and other characteristics associated with attributes of objects
  - Can be specific for a particular attribute/object pair
    - All power sensors might not provide the same accuracy
  - Frequency of sample collection can help determine usefulness of data
  - Can also, in some cases, set metadata
    - Potentially to change how a device responds

Statistics Interface

Sandia National Laboratories

PWR_AttrStat

```
typedef enum {
        PWR_ATTR_STAT_MIN = 0,
        PWR_ATTR_STAT_MAX,
        PWR_ATTR_STAT_AVG,
        PWR_ATTR_STAT_STDEV,
        PWR_ATTR_STAT_CV,
        PWR_NUM_ATTR_STATS,
        /* */
        PWR_ATTR_STAT_INVALID = -1,
        PWR_ATTR_STAT_NOT_SPECIFIED = -2
} PWR_AttrStat;
```

Statistics: Common Functionality

Sandia National Laboratories

- Statistics interface gathers data on one or more attributes for an object or group of objects
  - Real time or historic statistics
    - Historic implies data retention (database for example)
  - Min, Max, Average, Standard Deviation, Coefficient of Variation
  - Reduction operation available
  - User provided statistic function on the to-do list
- Provides functions to…
  - Start, stop, and reset statistics gathering
  - Get the calculated value(s) for the object or group of objects
  - Reduce the values calculated for objects in a group into a single value

Sandia National Laboratories

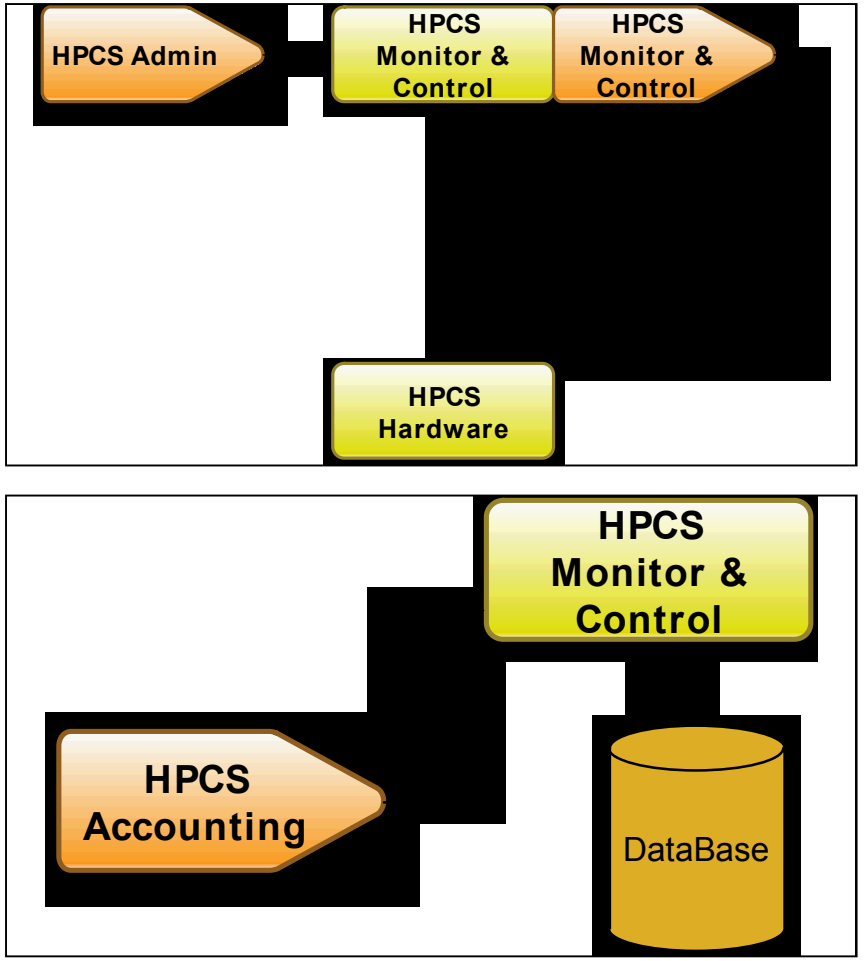
High Level Interfaces by Role (1)

Administrator:

- Apply Hard Power Limits based on Facility parameters
  - Bounds Power Aware Scheduling

Accounting:

- Power/Energy Application profiling based on historic information
  - Feeds into Power Aware Scheduling



High Level Interfaces by Role (2)

Resource Manager

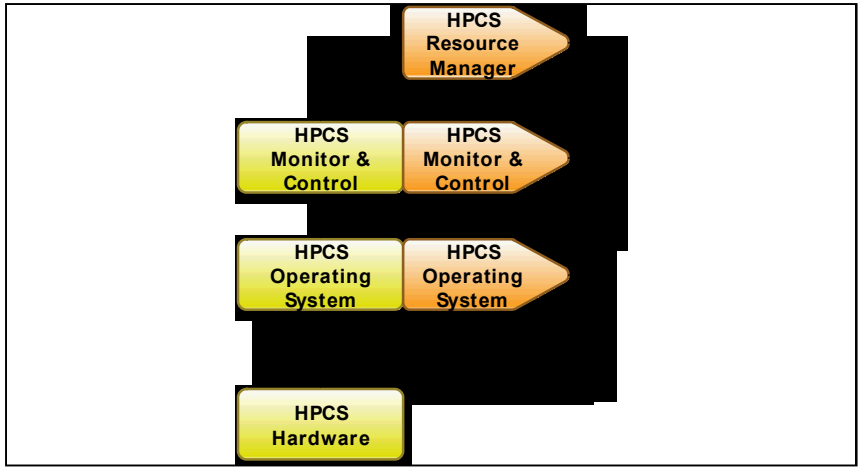
- Power Aware Scheduling
  - HPC Tetris

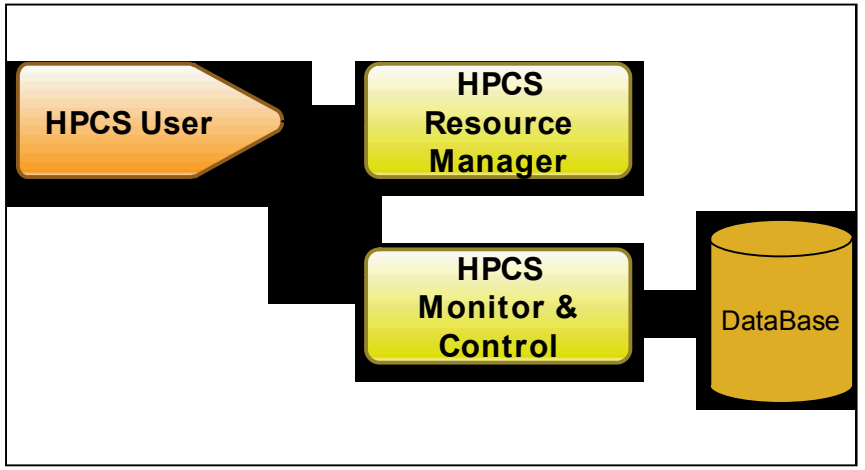
User

- Understands application Power and Energy Characteristics and Phases

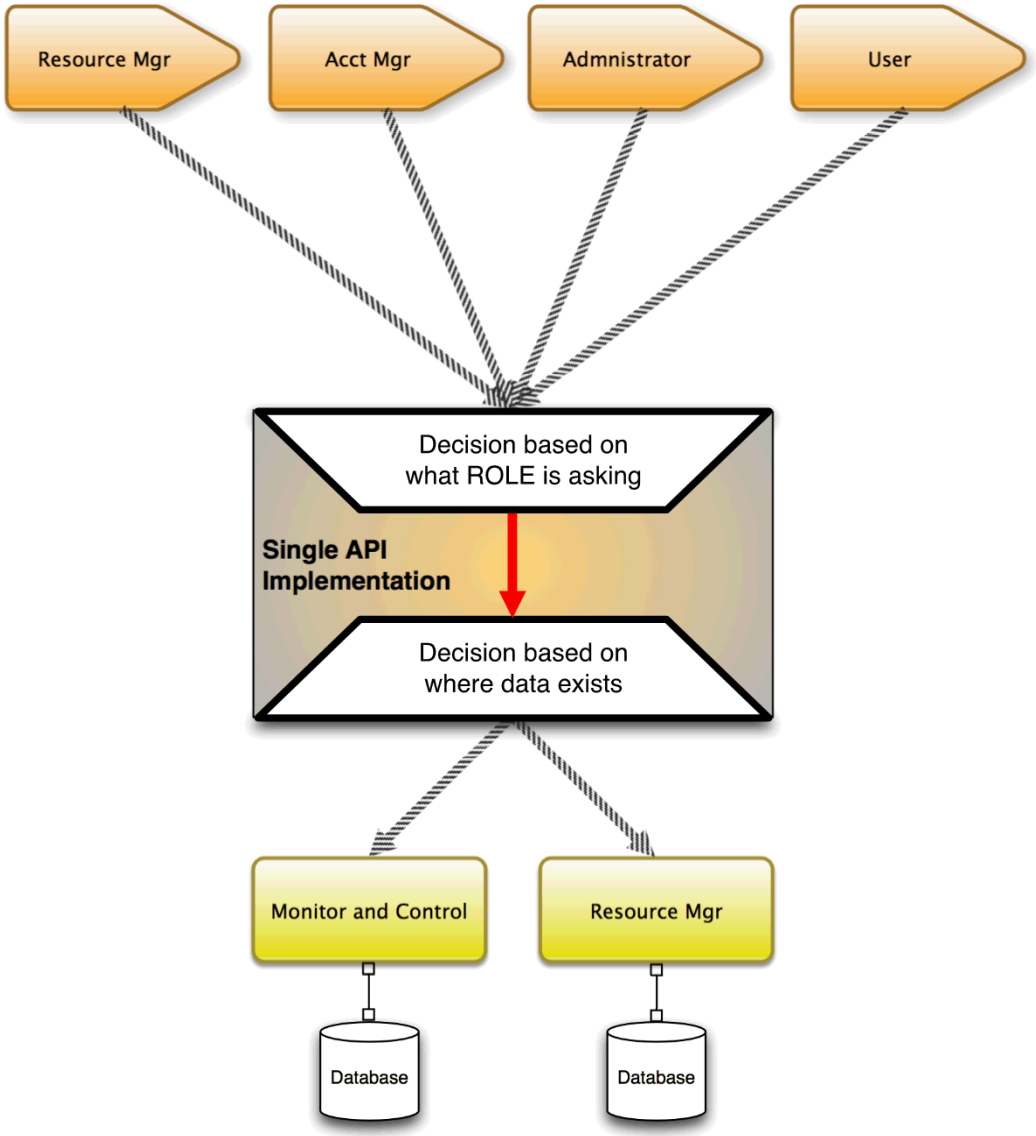
Application

- Provide application hints based on profiling

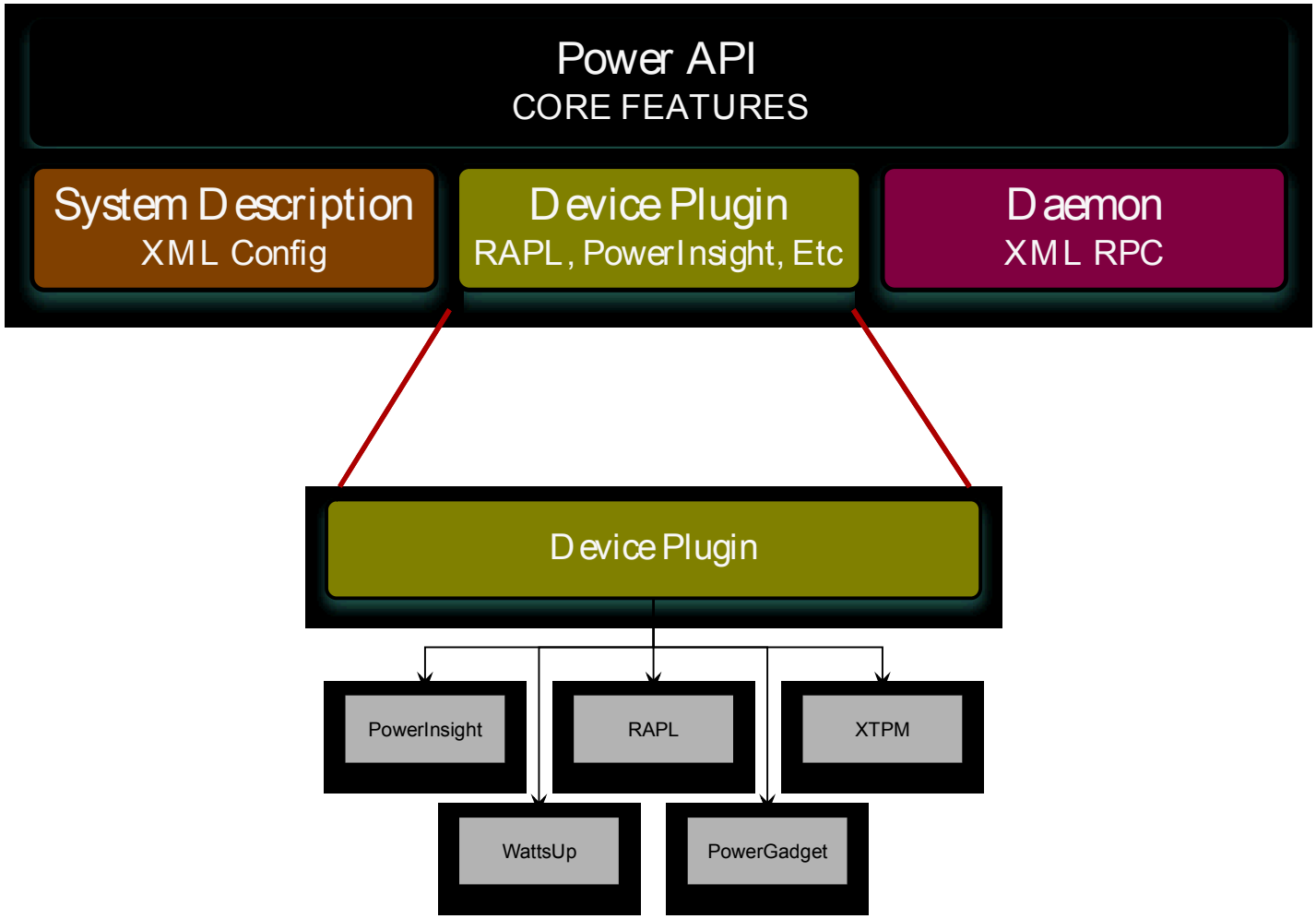




One Implementation Across Multiple Interfaces



Reference Implementation

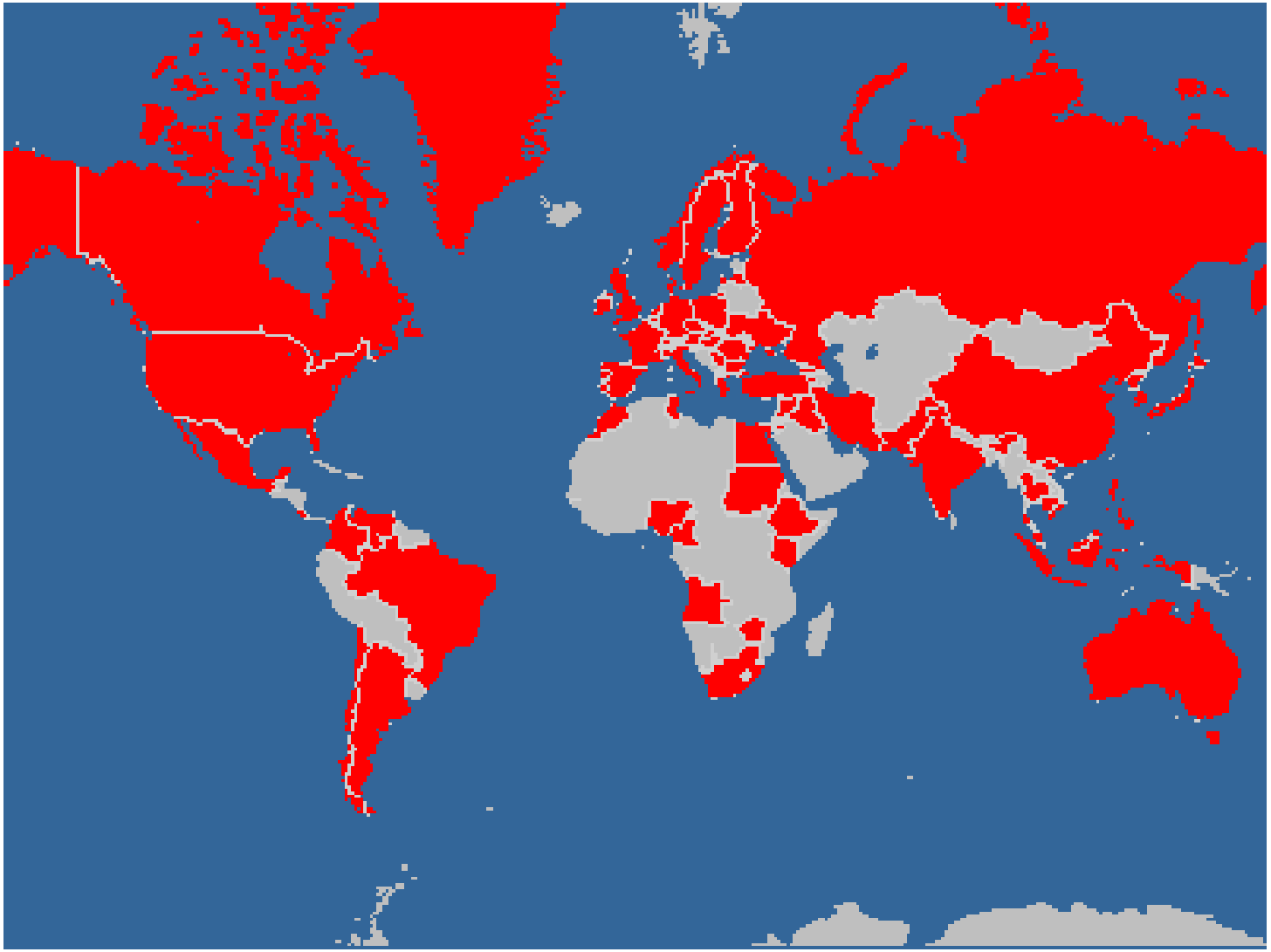


Available online and open source: http://github.com/pwrapi

Power API Timeline

Sandia National Laboratories

- 2013: Use case document prepared by SNL and NREL and reviewed by partners
- July 2014: Draft specification review meeting with cross-vendor panel of experts
- Aug. 2014: Specification v1.0 release (http://powerapi.sandia.gov/)
- Sept. 2014: Day-long community launch meeting with labs, industry, academia
- Jan. 2015: Prototype implementation release
- June 2015: Reference implementation release (http://github.com/pwrapi)
- Aug. 2015: Specification v1.1 release
- Oct. 2015: Specification v1.1a release (http://powerapi.sandia.gov/)



81 Countries as of October 2015

Trinity ATS-1 NRE: Advanced Power Management

Sandia National Laboratories

- DOE NNSA's Advanced Technology System (ATS-1)
  - >19,000 Nodes, <10MW
- Introduced the concept of funding Non-Recurring Engineering (NRE) projects to advance important technologies in conjunction with platform procurement
- Cray contracted to address Advanced Power Management
  - Implement portions of the Power API at scale

Targeting two areas of the API:

1. Implement interface to Power Management Database
   - Extend specification to include Python
   - Monitor and Control in our diagram
2. Compute node implementation (native C)

Going Forward

- How do we move forward?
- What “standards” model to apply?
- Regular calls?
  - Frequency?
- Face to Face meetings
  - Frequency?
- Important to have broad community participation which includes vendor representatives

Thank you – Questions?

Sandia National Laboratories

http://powerapi.sandia.gov/

Acknowledgments:

This work was funded through the Computational Systems and Software Environment sub-program of the Advanced Simulation and Computing Program funded by the National Nuclear Security Administration